New Immigrant Drosophilidae in Hawaii, and a Checklist of the Established Immigrant Species

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Abstract. Six immigrant species are added to the list of Drosophilidae of Hawaii. They are: *Amiota* sp, *Drosophila bizonata* Kikkawa and Peng, *D. nasutoides* Okada, *Hirtodrosophila* sp. nr. *unicolorata* Wheeler, *Scaptodrosophila* sp., and *Scaptomyza pallida* (Zetterstedt). Seven new island records of previously established species are also documented. An annotated list of the 32 immigrant species of Drosophilidae established in Hawaii is provided, with the earliest confirmed year of detection for each species.

Key words: Drosophilidae, Hawaii, Distribution

The family Drosophilidae consists of 3950 valid species (Brake and Bächli 2008). With 559 endemic species (O'Grady et al. 2009), and an estimated 900-1000 in total, the Hawaiian Islands have the highest regional drosophilid species diversity globally.

Five species of immigrant Drosophilidae were listed as occurring in Hawaii by early authors (Sturtevant 1921, Bryan 1934), but most of these records were later shown to be misidentifications. Zimmerman (1943) was the first to document thoroughly the immigrant Hawaiian drosophilid fauna, based on available material in collections and field surveying. He pointed out that the species of *Drosophila* recorded in early literature as *D. immigrans*, *D. repleta*, *D. mulleri*, and *D. melanogaster* were actually *D. sulfurigaster*, *D. hydei*, *D. carinata* and *D. simulans*, respectively. Additionally, he provided the first records of field capture of *D. ananassae*, *D. kikkawai*, and the true *D. melanogaster.* In his comprehensive monograph, Hardy (1965) included 21 immigrant species, a few of which may not have actually been established. More recently, Nishida (2002) listed a total of 28 immigrant species, including 1 dubiously established species, 1 specied detected in quarantine interception but not established, and 3 deliberately introduced biological control agents that failed to establish.

This paper reports the capture of new immigrant species and provides an up-to-date annotated checklist (Table 1) of the established immigrant species, with the earliest confirmed collecting date for each species. Species previously listed in checklists or catalogues but probably not established in Hawaii are excluded from the table and discussed below.

New State and Island Records

The additional immigrant species and new island records presented here resulted mostly from trapping on the islands Hawaii (May to August 2005) and Maui (May to November 2006) as part of a study on the nontarget effects of fruit fly (Tephritidae) lures (Leblanc et al. 2009). On the Big Island (Hawaii), male lure (Leblanc et al. 2009) and BioLure (Heath et al. 1997) traps were placed in predominantly native or mixed (native and introduced plants) forests along the Stainback Highway, Saddle Road and in the North Kohala Forest

Reserve, as well as in the agricultural community of Waimea. On Maui, traps were maintained in the agricultural community of Kula and in the Waikamoi, Makawao and Koolau Forest Reserves. All the species listed in Table 1 were collected during the study, except for *Dettopsomyia formosa*, *Drosophila carbonaria*, *D. polychaeta*, *D. repleta*, *D. virilis*, *S. pallida* and *Mycodrosophila* spp. The most abundant species in the traps were *D. suzukii*, *D. sulfurigaster bilimbata* and *D. immigrans*. Individual trapping locations for the new records are referred to by their numbers, as presented on maps on Figures 1 to 4 in Leblanc et al. (2009). Voucher specimens of most of the species recorded here are deposited at the University of Hawaii Insect Museum (University of Hawaii Manoa, Honolulu).

***Amiota* sp. (New state record). Oahu**: Waianae Mountains (700 m): Puu Kalena, 23.viii.2007, Steve Montgomery, attracted to bait. This undetermined species belongs to a genus of 116 species and present in all regions worldwide, but predominantly the East Palearctic (Brake and Bächli 2008).

***Drosophila bizonata* Kikkawa and Peng (New state record).** Although a few specimens were bred from mushrooms imported from Japan and intercepted by quarantine inspectors in 1960 (Hardy 1960), *D. bizonata* was not collected in the field until recently (Leblanc et al. 2009). It is well established and common in the agricultural areas of Waimea and Kula, and occurs in smaller numbers in endemic forest. It is a polyphagous pest of mushrooms in Japan (Iwamura and Nobuchi 1954, Yamashita and Hijii 2007). **Hawaii**: Kohala (924–1,019 m): 6 specimens among sites 25, 27 and 28, 11-31.vii.2005; Waimea (744–872 m): common (2.2 per positive trap per day) at all five sites, 22.vi–7.viii.2005. **Maui**: Kula (517–1,138 m): common (0.2 per positive trap per day) at sites 36, 37, 38, 40, 42, 43, 44, 2.vi–27.xi.2006; Maui forest (1,291–1,455 m): one specimen trapped at each of eight sites (51, 52, 57, 58, 60, 61, 78, 79), 19.vi–21.viii.2006.

***Drosophila cardini* Sturtevant (New island records). Hawaii**: Waimea (744 m): 1 specimen at site 31, 22.vi.2005. **Maui**: Kula (610–881m): 13 specimens among sites 37, 38, and 43, 9.vi–16.viii.2006.

***Drosophila nasutoides* Okada (New state record). Oahu:** Manoa Cliff trail: 1 specimen taken by sweeping, 19.x.2008, Patrick O'Grady.

***Drosophila quadrilineata* de Meijere (New island records). Hawaii**: Stainback (138–904 m): 11 specimens among sites 2, 4, 5, 6, and 9, 14.vi–10.viii.2005; Kohala (912–1,019 m): 36 specimens among sites 25 to 29, 27.vi–31.vii.2005; Waimea (839-87 2m): 4 specimens at sites 32-33, 6.vii–1.viii.2005. **Maui**: Kula (1,037m): 1 specimen at site 40, 4.viii.2006; Maui forest (1,200-1,293 m): 21 specimens among sites 60, 76, 78, and 79, 1-21.viii.2006.

***Hirtodrosophila* sp. nr *unicolorata* Wheeler (New state record).** This very small species belongs to a large genus of fungus-breeders, with 159 species present in all regions of the world (Brake and Bächli 2008). This new immigrant species is very similar to *H. unicolorata*, known from Samoa, the Philippines and Thailand (Evenhuis and Okada 1989, Brake and Bächli 2008), but lacks the diagnostic black spot at the base of the wing seen in *H. unicolorata*. **Hawaii**: Saddle road (674–1,975 m): 17 specimens among sites 11, 19, 20, and 23, 11.vi–30.vii.2005; Kohala (959–1,019 m): 20 specimens among sites 25 to 27, 27.vi–25.vii.2005; Waimea (859–872 m): 4 specimens at sites 33 and 35, 22.vi–25.vii.2005. **Maui**: Kula (881–1,138 m): 15 specimens among sites 38, 43 and 44, 16.vi–27.xi.2006; Maui forest (1,290–1,438 m): 2 specimens, at sites 52 and 64, 6-20.vi.2006.

***Scaptodrosophila* sp. (New state record).** With 279 species worldwide (Brake and Bächli 2008) and 136 species in the Austro-Pacific region (Evenhuis and Okada 1989), it is not possible to assign our series, composed exclusively of females, to a species. It is a new state record for the genus. **Hawaii**: Stainback (173–397 m): 35 specimens, at sites 6 and 8, 10.vi–10.viii.2005.

***Stegana coleoptrata* (Scopoli). (New island record). Hawaii**: Stainback (175 m): 1

female at site 8, 24.i.2006.

***Zaprionus ghesquierei* Collart. (New island records). Hawaii**: Stainback (175m): 3 specimens at sites 7 and 8, 10–21.vi.2005. **Maui**: Kula (517–1,055 m): 45 specimens, among sites 36 to 40, and 43, 2.vi–27.xi.2006; Maui forest (1,290 m): 1 specimen at site 80, 27.vii.2006.

Species Questionably Established in Hawaii

***Drosophila funebris* (Fabricius, 1787).** This species was reported by Hardy (1965), based on one specimen (Kula Pipeline, Maui, 1932), with no evidence that it had established. It was not collected during recent extensive trapping in Maui. It is a sap-breeding species in its native range, and may not have been sampled recently because sap flux is a rare and poorly studied resource.

***Drosophila sulfurigaster sulfurigaster* (Duda, 1923).** This subspecies, cited for Hawaii by Nishida (2002), occurs in Southeast Asia, Australia, Indonesia, and as far east as the Solomon Islands, whereas *D. sulfurigaster bilimbata* is widespread over the Pacific Islands (Evenhuis and Okada 1989).

***Pseudiastiata* spp.** Three separate species of these mealybug predators were introduced and released between 1924 and 1937 to control pineapple mealybug, *Dysmicoccus brevipes* (Cockerell) (Pseudococcidae) (Fullaway 1933, Carter 1935). They were imported under the name of *P. nebulosa* Coquillett, but were actually three species from the Neotropical region, *P. nebulosa* being Eastern Nearctic (Hardy 1959). The three are *P. brasiliensis* Costa Lima (from Brazil), *P. pseudococcivora* Sabrowsky (from Central America), and *P. vorax* Sabrowsky (from Trinidad). None of the species were ever subsequently recovered (Hardy 1952a, 1965). However the generalist mealybug drosophilid predator *Cacoxenus perspicax* (Knab) is an accidental immigrant that feeds on a broad diversity of mealybugs (Bianchi 1940, Hardy 1965).

***Scaptomyza graminum* (Fallén 1823).** The immigrant *Scaptomyza elmoi* was originally recorded as *S. graminum*, a leafminer, by Hardy (1952b), based on a collection on Oahu in 1951. Its identity was later confirmed by W. Hackman (cited in Hardy 1965) to be actually *S. pallida* (Zetterstedt 1847), a scavenger. Previous records of *S. pallida* in Hawaii were subsequently demonstrated by Takada (1970) to be actually a new species of Asian origin, separate from the true Asian *S. pallida*, which was described as *S. elmoi* Takada 1970. Recently, however, Patrick O'Grady has collected the true *S. pallida* by sweeping at the Manoa Cliff Trail, in 19 October 2008. Species identity was ascertained by dissecting the male genitalia. This species is probably established, especially on Oahu.

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Table 1. List of immigrant Drosophilidae established in Hawaii.

Species Comments	Distribution[1]	Earliest known collection in Hawaii	Origin
Subfamily Drosophilinae			
Chymomyza procnemis (Williston 1896)	O, Mo, L, Ma, H	1936 (Bryan 1938, Zimmerman 1938)	Neotropical
Dettopsomyia formosa Lamb 1914	O, Mo, Ma, H	1936 (Malloch 1938)	Tropical Asia or South Pacific
Dettopsomyia nigrovittata (Malloch 1924)	K, O, Mo, L, Ma, H	1950 (Hardy 1956)	Uncertain (Circumtropical)
Drosophila (Dorsilopha) busckii Coquillett 1901	K, O, Ma, H	1945 (Davis 1947)	Uncertain (Cosmopolitan)
Drosophila (Drosophila) bizonata Kikkawa and Peng 1938	Ma[2], H[2]	1960 (not established) and 2005[2]	Asia (Japan ?)
Originally bred from mushroom from Japan intercepted by quarantine (Hardy 1960, 1965). Collected recently (Leblanc 2009).			
Drosophila (Drosophila) carbonaria Patterson and Wheeler 1942	O, Mo, H	1995 (O'Grady et al. 2002)	SW USA or Mexico
Larvae bred on monkeypod flux in Hawaii (O'Grady et al. 2002).			
Drosophila (Drosophila) cardini Sturtevant 1916	O, Ma[2], H[2]	1983 (Kaneshiro 1986)	S USA, Neotropical
Drosophila (Drosophila) hydei Sturtevant 1921	K, O, Mo, L, Ma, H	ca. 1900 (Sturtevant 1921)	Uncertain (Cosmopolitan)
Zimmerman (1943) confirmed that early *D. repleta* records actually of *D. hydei*.			
Drosophila (Drosophila) immigrans Sturtevant 1921	K, O, Mo, L, Ma, H	1948 (Mainland 1949)	Uncertain (Cosmopolitan)
Early records of *D. immigrans* were actually of *D. sulfurigaster bilimbata* (Zimmerman 1943, Mainland 1949).			
Drosophila (Drosophila) mercatorum Patterson and Wheeler 1942	K, O, Mo, L, Ma, H	1892 (Grimshaw 1901, Hardy 1965)	S USA, Neotropical
Hardy (1965) reported this species under the name *D. carinata*. This name is no longer valid and was replaced by *D. mercatorum* by Melville (1977).			
Drosophila (Drosophila) nasutoides Okada 1964	O[2]	2008[2]	Probably Samoa
NEW STATE RECORD			
Drosophila (Drosophila) polychaeta Patterson and Wheeler 1942	K, O, H	1948 and 1970	S USA, Neotropical
First reported by Hardy (1952a), but not re-discovered until 1970 (Wheeler and Kaneshiro 1974).			
Drosophila (Drosophila) quadrilineata de Mejire 1911	O, Ma[2], H[2]	1995 (Beardsley et al. 1999)	Tropical Asia or Micronesia
Drosophila (Drosophila) repleta Wollaston 1858	O, Mo, L, H	1948 (Mainland 1949)	Uncertain (Cosmopolitan)
Early literature records of *D. repleta* were actually *D. hydei* (Zimmerman 1943).			
Drosophila (Drosophila) sulfurigaster bilimbata Bezzi 1928	K, O, Mo, L, Kh, Ma, H	1898 (as *D. immigrans*, by Sturtevant 1921)	South Pacific
Early records of *D. immigrans* were on this species (Zimmerman 1943). Misidentified as *D. nasuta* in Hardy (1965).			
Drosophila (Drosophila) virilis Sturtevant 1916	Ma	1971 (Wheeler and Kaneshiro 1974)	Uncertain (Widespread)
Drosophila (Phloridosa) lutzii Sturtevant 1916	O, Ma, H	1979 (Hardy 1982); 1963 (first detection by H. Carson, according to Montague and Kaneshiro 1982)	New World Tropics
(= *D. floricola* Sturtevant 1942, synonymized by Vilela and Bächli 1990). Larvae breed on decaying flowers of morning glory. Probably introduced in cut flowers (Hardy 1982).			

Drosophila (Sophophora) ananassae Doleschall 1858	K, O, H	1942 (Zimmerman 1943)	Uncertain (Pantropical)
Drosophila (Sophophora) kikkawai Burla 1954	K, O, Ma, H	ca. 1942 (Zimmerman 1943)	Uncertain (Pantropical in Neotropics and Asia-Pacific)
First record by Zimmerman (1943), as *D. montium* de Meijere.			
Drosophila (Sophophora) melanogaster Meigen 1830	K, O, Mo, L, Kh, Ma, H	1907 (Hardy 1965)	Uncertain (Cosmopolitan)
Most early literature records were based on misidentifications of most probably *D. simulans* (Hardy 1965).			
Drosophila (Sophophora) simulans Sturtevant 1919	K, O, Mo, L, Ma, H	1903 (Hardy 1965)	Uncertain (Cosmopolitan)
Drosophila (Sophophora) suzukii (Matsumura 1931)	K, O, Mo, Ma, H	1980 (Kaneshiro 1983)	Eastern Asia
Recorded as high as 4000 ft by O'Grady et al. (2002).			
Hirtodrosophila sp. nr. *unicolorata* Wheeler 1959	Ma[2], Ha[2]	2005[2]	Asia or South Pacific
NEW STATE RECORD			
Mycodrosophila sp (or spp)	O, Ma, H	1969 (O'Grady et al. 2002)	Asia-Pacific?
O'Grady et al. (2002) reports at least one species, from Oahu and Maui, but Wheeler and Kaneshiro (1974) had reported the collection of at least two distinct species on Maui and Hawaii, without further details.			
Scaptodrosophila sp	Ha[2]	2005 (New record)	Uncertain (Numerous species)
NEW STATE RECORD			
Scaptomyza (Parascaptomyza) elmoi Takada 1970	K, O, Mo, Ma, H	1925 (Hardy 1965)	Asia
Erroneously recorded as *S. graminum* (Hardy 1952b) and *S. pallida* (Hardy 1965).			
Scaptomyza (Parascaptomyza) pallida (Zetterstedt 1847)	Oa	2008 (New record)	Uncertain (Cosmopolitan)
The first record of the real *S. pallida* in Hawaii.			
Zaprionus ghesquierei Collart 1937	O, Mo, Ma[2], Ha[2]	1978 (O'Grady et al. 2002)	Africa
Subfamily Steganinae			
Amiota sp	Oa[2]	2007 (New record)	Most Likely Asia
NEW STATE RECORD			
Cacoxenus perspicax (Knab 1914)	O, Mo, Ma, H	1902 (Knab 1914)	Asia
Larvae are generalist mealybug predators (Bianchi 1940, Hardy 1965).			
Leucophenga maculosa (Coquillett 1895)	O, Mo, L, Ma, H	1971 (Wheeler and Kaneshiro 1974)	New World widespread
Stegana coleoptrata (Scopoli 1763)	O, Mo, Ha[2]	1976 (O'Grady et al. 2002)	North America

[1] K: Kauai, O: Oahu, Mo: Molokai, Kh: Kahoolawe, L: Lanai, Ma: Maui, H: Hawaii.
[2] New Island or State record.

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